VITESSE SEMICONDUCTOR CORPORATION

Gallium Arsenide: a Faster Alternative to Silicon for Microprocessors and Telecommunications Applications

Nearly all integrated circuits (ICs) are manufactured on a substrate of silicon. The silicon chip has provided the base on which IC technology has advanced. But silicon has its limits. Electrons pass through GaAs about five times faster than through silicon, suggesting potential for achieving higher processing speeds from ICs fabricated from GaAs. In the 1970s and 1980s, research efforts were undertaken to develop gallium arsenide (GaAs) as an alternative material for fabricating integrated circuits.

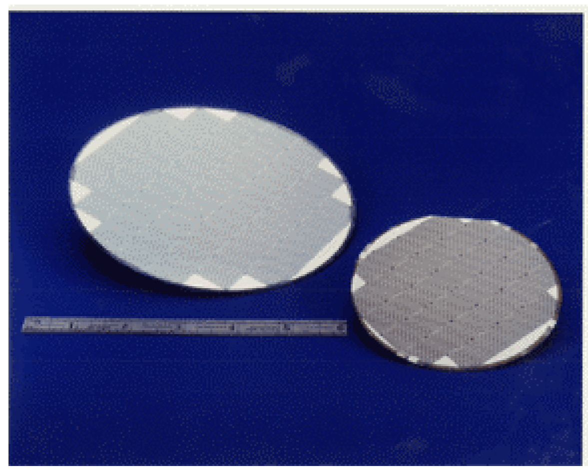
COMPOSITE PERFORMANCE SCORE
(based on a four star rating)
* * *

Barriers to Use of GaAs-based ICs

Despite their speed advantage, GaAs-based ICs, developed in the 1980s, did not find widespread commercial use. One barrier to their use was price. GaAs cost as much as 10 times more than silicon in the early years. The wafers from which GaAs chips are made were difficult to produce without a high level of defects. And, they were difficult to produce at all. More recently, this cost barrier has been significantly reduced as wafer suppliers and chip producers have perfected manufacturing techniques.

Another barrier to widespread commercial use of GaAs-based ICs was their high power consumption. Unlike silicon ICs, which consume power only while performing processing tasks, GaAs ICs consume power even when they are not in operation. The use of GaAs as a substrate for ICs had been pioneered for military applications, namely in microproccessors for supercomputing. Military users were willing and able to pay the considerable premium for GaAs-based chips in return for superior processing speed. Commercial users, however, saw the high power requirements as an unacceptable obstacle.

The high power requirements placed limits on the exploitation of the inherent speed advantage of GaAs. More wiring was needed to transmit more power to the chip, crowding out the wiring needed to transmit the input and output signals; thus fewer transistors could fit on the same chip. So constrained, GaAs technology had to employ several chips to equal the capacity of a single silicon chip, causing much of the speed advantage of GaAs to be lost in the time delays between chips.



Vitesse's ability to fabricate chips on 6" wafers in it's new plant, (instead of 4" wafers) more than doubles the number of integrated circuits that can be fabricated on each wafer and increases the efficiency of production.

The ability of GaAs to compete with silicon for use in ICs was contingent on design innovations that allow the particular advantages of GaAs to be exploited effectively. The years of accumulated design and manufacturing process refinements, however, had been devoted to silicon-based ICs, not GaAs-based ICs.

PROJECT HIGHLIGHTS

Project:
To achieve design innovations needed to exploit the speed and power advantage of GaAs, a substrate material for fabricating high-performance integrated circuits (ICs) for use in microprocessors, transceivers, and ICs used in automatic testing equipment.

Duration: 3/01/94 – 12/31/96
ATP Number: 93-01-0124
Funding (in thousands):

ATP	$ 2,000	30%
Company	4,634	70%
Total	$6,634	

Accomplishments:
Initial applications of GaAs design innovations in the development of a super microprocessor for use in supercomputers and workstations were abandoned due to market uncertainty. Vitesse refocused its efforts on the development of GaAs design innovations for transceivers used in telecom-munications and data communications, and for ICs used in automatic test equipment. Project accomplishments included:

- 400 percent increase in memory per chip;

- 50 percent decrease in size of an IC for equivalent functionality;

- 50 percent reduction in power consumption;

- GaAs design innovations commercialized as H-GaAs IV-based technology in transceivers and ATE;

- construction of a new, more efficient chip fabrication plant to fabricate GaAs chips on six inch wafers instead of four inch wafers;

- disseminated the technology through articles in the Electronic Engineering Times, Computer Design Magazine, Lightwave, and Semiconductor FabTech; and

- enabled ATE producers to be able to test increasingly fast ICs.

Commercialization Status:
The design innovations in GaAs have been commercialized in the form of H-GaAs IV–based IC technology. It is being applied to transceivers for use in telecommunications and data communications, which now account for approximately 80 percent of Vitesse's revenues. H-GaAs IV–based ICs are also used in automated test equipment (ATE), accounting for the remaining 20 percent of Vitesse's revenues. Virtually all ATE makers have purchased H-GaAs IV–based ICs from Vitesse. Every Intel Pentium microprocessor built has been tested by ATE using Vitesse ICs. Success in these markets has allowed Vitesse to build a new and more efficient chip fabrication plant.

Outlook:
Full commercialization is expected after refinements to the technology based on feedback from customers using prototype units. If the technology is commercialized, its users — aircraft manufacturers, airlines and their passengers — will benefit from brighter, more reliable and cheaper backlights for flat-panel displays in airplane cockpits.

Composite Performance Score: * * *

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Vitesse Proposes GaAs Design Innovations

Vitesse Semiconductor Corporation, at that time a small company, proposed a project for GaAs innovations in ATP's 1993 General Competition. ATP made an award of $2 million to Vitesse for a 33-month project, later extended to the maximum allowable period of three-years. Vitesse contributed $4.6 million, bringing total project costs to $6.6 million.

The company, located in Camarillo, California, has become a world leader in the design, development, and manufacture of GaAs ICs. It pioneered the development of Very Large Scale Integration (VLSI) in GaAs, and also pioneered the adaptation of proven state-of-the-art silicon chip manufacturing equipment to the production of GaAs chips to reduce their cost and improve reliability.

Project Goals and Early Results

The project's first objective was to shrink the size of and reduce power consumption of GaAs-based ICs by creating a super microprocessor. By replacing multiple chips with a single-chip super microprocessor, transfer delays would be eliminated and the speed advantage of GaAs fully realized. Two secondary objectives were to use the improved GaAs ICs in communications applications and automatic testing equipment (ATE).

The research started with the development of electrical and process models to help determine the optimal design of GaAs ICs that would exploit their speed advantage. With the insights provided by these simulations, Vitesse created a library of basic IC components that permitted the construction of a demonstration vehicle to test design performance. The initial demonstration vehicle was a microprocessor, which, in turn, was to be used to test designs of the super microprocessor.

Market Changes Compel Reorientation of Project

Unexpectedly, Vitesse was forced to abandon its super-microprocessor objective at the end of the first year of the project. Although the supercomputer and workstation markets for GaAs supermicroprocessors appeared to be a reasonable target at the time of the project's proposal and selection, subsequently the market for supercomputers steeply declined. The

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decline was due in in part to the collapse of government and aerospace demand for supercomputers. Early in the project, Convex Computers, the only supercomputer producer using GaAs-based microprocessors (and Vitesse's only customer in this application) suffered serious losses. Convex Computers had accounted for half of Vitesse's revenues.

Vitesse confronted a large investment risk in entering the high-performance microprocessor market. Higher performance microprocessors are split between two competing standards: complex instruction set computers (CISC) and reduced instruction set computers (RISC). Within these broad classes, many fundamental architectural differences exist, each with its own specific demands. Vitesse would have to bet on one. Moreover, Vitesse would have to supply compilers, linkers, math libraries, and other high-level software to complement any microprocessor that it chose to make. This would require a daunting investment of up to $30 million. *1* The company's financial condition and the uncertainty characterizing the direction of the high-performance microprocessor market led Vitesse to seek alternative opportunities for GaAs technology during the first year of the project.

Vitesse requested a change in the project, and ATP agreed to allow a change in focus on developing and testing GaAs design innovations for use in the development of wire-line transceivers and ICs for automatic test equipment (ATE). This use for GaAs IC technology was on the rise. Networks of workstations, configured to emulate a supercomputer at far less cost, were becoming increasingly popular, and these workstations, like other local area networks (LANs), require the use of transceivers for data transmission and error-checking.

There are also many other applications for transceivers. They are essential in telephone communications that share large volumes of digital data among various points, such as central switching offices and cellular transmission sites. Credit card companies also rely on transceivers for the data links that connect databases and terminals, ensuring speedy authentication during transactions. Transceivers will also be an essential component in digital television. Transmission of digital television signals from television stations to home sets, between the cameras and the studio, and between the studio and the network facilities will all require very high-speed links with transceivers at either end.

ATP Flexibility Important to Company's Future Success: Funding Supports Critical Shift in Business Strategy

By accepting Vitesse's request that it be allowed to shift the project's focus for applying the technology rather than stopping the project, ATP enabled Vitesse to continue the development of GaAs technology following the business reverses of its main customer. According to Ray Milano of Vitesse, ATP funding was essential for sustaining its development of GaAs technology. Accomplishments in the project ultimately allowed the company to build its position in wire-line transceivers and ICs for automatic testing equipment. *2*

Design Innovations Achieved

Vitesse made substantial progress toward the revised project goals. Vitesse designated the new generation of GaAs IC technology developed from the project's design innovations as H-GaAs IV. The H-GaAs IV embodies a 50 percent decrease in size for equivalent functionality, and requires just half as much power to deliver the same amount of processing speed. Memory per chip was increased four-fold.

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Higher levels of integration and reduced power consumption made possible by project-related design innovations have allowed Vitesse to provide GaAs-based ICs with clear advantages over traditional silicon-based ICs, both for transceivers and ICs for automatic testing equipment (ATE).

1 This estimate was developed in discussions between Vitesse and Compaq, a prospective customer and development partner.

2 In-person communication between Phil Perconti, ATP, and Ray Milano, Vitesse, March 1999.

Project Innovations Embodied in Transceivers and ATE Equipment

The old technology for ATE employed multiple, linked silicon ICs to perform the same task as one H-GaAs IV IC. The greater number of connections required to link

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he silicon ICs with the IC to be tested, the greater space they took up, the power consumed, and the amount of heat generated caused ATE producers to be very receptive to Vitesse's H-GaAs IV. Virtually all ATE makers, including Intel, have purchased GaAs chips from Vitesse. Every Pentium microprocessor built has been tested by ATE using Vitesse ICs.

Overall, the chief commercial application of H-GaAs IV-based IC technology has been for transceivers used in telecommunications and data communications. Customers include telecommunication equipment makers such as Lucent Technologies, Alcatel, and Ericsson.

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Success in these markets allowed Vitesse to build a major new chip fabrication plant. This plant will fabricate chips on six-inch wafers. Heretofore, GaAs ICs have been fabricated on four-inch wafers. The shift to six-inch wafers will more than double the number of ICs that can be fabricated on each wafer, dramatically increasing the efficiency of GaAs IC production.

…substantial cost and performance advantages over silicon ICs…

Producers and Customers Benefit from Lower Costs, New Capabilities

H-GaAs IV-based ICs offer a superior alternative to silicon-based transceivers. Because just one IC must be purchased, and because the Vitesse transceiver consumes less power than the set of silicon ICs, total system cost is substantially less.

H-GaAs IV IC technology has been instrumental in meeting the needs of ATE producers and their customers. The ICs used in ATE must be faster than the ICs to be tested. Silicon technology was running up against technical limits. H-GaAs IV IC technology has allowed ATE producers to overcome the technological bottleneck and produce equipment with the capability to test increasingly fast ICs.

Increased levels of integration and reduced power consumption made possible by project-related design innovations in GaAs-based IC technology have enabled Vitesse to provide substantial cost and performance advantages over silicon ICs, both for transceivers and for ICs used in automatic testing equipment.

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